
Overview of NABC 21: Adapting Agriculture to Climate Change

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NABC's twenty-first annual conference convened in Saskatoon, June 24–26, 2009, hosted by the College of Agriculture and Bioresources at the University of Saskatchewan. The focus was mainly on the complex issues involved in adapting crop agriculture to climate change, with minor comments on mitigation; animal agriculture was not addressed. The sixty delegates were welcomed by Graham Scoles (NABC-21 program chair, dean of the College of Agriculture and Bioresources), Peter MacKinnon (president of the University), Alanna Koch (deputy minister of agriculture for Saskatchewan) and Allan Eaglesham (NABC executive director, for NABC President Ralph Hardy). Plenary sessions were held on the afternoon of June 24, the morning and afternoon of June 25, and the morning of June 26.

The keynote speaker at the June 25 banquet—held at the Western Development Museum—was Sylvain Charlebois (associate dean and director of the Levene Graduate School of Business at the University of Regina, Regina), whose presentation was titled *Opportunities of the Commons: Agriculture's New Frontier*.

The conference was structured in four modules, after each of which two parallel breakout sessions were scheduled (see p. 13). The breakout session after Module 2 was cancelled due to over-run of the prior, lively Q&A session. Three panelists reacted to the plenary presentations with brief remarks after Modules 2, 3 and 4, after which Q&A sessions involved audience participation (including Module 1).¹

Module 1—*Climate Change Overview and Projections*—comprised presentations by Francis Zwiers (Canadian Centre for Climate Modelling and Analysis, Toronto, *Our Evolving Climate*), Raymond Desjardins (Agriculture and Agri-Food Canada, Ottawa, *The Impact of Agriculture on Climate Change*), and Linda Mearns (Institute for the Study of Society and Environment, Boulder, *The Impact of Climate Change on Agriculture*).

In Module 2—*Genetic Approaches to Crop Adaptation*—presentations were made by Tim Sutton (University of Adelaide, Adelaide, *Functional Genomics and Abiotic Stress Tolerance in Cereals*), Malcolm Devine (Performance Plants, Saskatoon, *Enhancing Crop*

¹Transcripts of the panelists' remarks and the Q&A sessions will be included in the proceedings volume, *NABC Report 21*.

Productivity Through Increased Abiotic Stress Tolerance and Biomass), and Michael Metzloff (Bayer BioScience NV, Ghent, *Adapting Crops to Climate Change*).

The speakers in Module 3—*Other Approaches to Adaptation*—were Don Smith (McGill University, Montreal, *Living With It: Adapting Crop-Production Systems to Emerging Climate Change*), Jeffrey White (US Arid Land Agricultural Research Center, Maricopa, *Adapting Cropping Patterns to Climate Change*), and Rattan Lal (Ohio State University, Columbus, *Soil and Water Management Options for Adaptation to Climate Change*)

Presentations in Module 4—*Ethics, Policy, Carbon Credits*—were made by Harold Coward (University of Victoria, Victoria, *Ethical Issues in Adaptation and Mitigation Responses to Climate Change*), Gordon McBean (University of Western Ontario, London, *Adapting to Climate Change: The Challenges and Opportunities in an Uncertain Policy Environment*) and Benjamin Gramig (Purdue University, West Lafayette, *Greenhouse Gas Emissions Offsets from Agriculture: Opportunities and Challenges*)

Issues of interest raised by the speakers included the following.

CLIMATE-CHANGE OVERVIEW AND PROJECTIONS

- That global warming is occurring is unequivocal. The evidence comes from air temperatures and ocean temperatures, from reductions in the amounts of ice and snow on the surface of the planet, and from changes in sea level because additional water is being stored in the oceans and because the oceans are being warmed. Although there is a great deal of natural internal variability in the system, strong evidence suggests that human activity has been driving these temperatures upwards for the past century.
- Over the past 100 years, the concentration of carbon dioxide (CO₂) in the atmosphere has risen by approximately 100 ppm. That CO₂ has come from our use of fossil fuels and of the land surface, causing movements of carbon from fossil and soil reservoirs into the atmosphere.
- Using computer-simulation models, we can do a pretty good job of reproducing the history of the twentieth century on a global scale by taking into account the effects of human and natural external factors on the climate system. If we leave out human factors and consider only the natural factors—solar and volcanic forcing—then we cannot explain the rapid warming that occurred during the latter part of the twentieth century.
- Aerosols that are abundant in the environment as dust particles (from bare soil and plant residues), or as anthropogenic residues of combustion (from crop burning), can have a significant cooling effect. They have a direct effect on the radiation budget by scattering and absorbing short-wave and long-wave radiation. They also have an indirect radiative effect by influencing cloud formation, which may then lead to changes in the incoming solar radiation.
- Globally, agriculture accounts for 13% of the radiative forcing related to greenhouse gases (GHGs); in Canada and the United States it accounts for 6% to 8%.

The GHG emissions in Canada and the United States are mainly in the form of methane (CH_4) and nitrous oxide (N_2O). Agricultural sources such as animal husbandry, manure management and agricultural soils account for about 52% of global CH_4 and 84% of global N_2O emissions. In the past, deforestation and intensive agriculture (*e.g.* grassland cultivation) have contributed significantly to the increase in atmospheric carbon dioxide CO_2 . For example, until the 1970s, more CO_2 had been released into the atmosphere from agricultural activities than from fossil-fuel burning.

- Agricultural activities can influence climate through land-use change, which can modify the albedo of the Earth's surface. The albedo in an agricultural context depends on a variety of factors including crop type, crop, management practice, surface condition, time of day and time of year.
- In the past 20 years, about 75% of the CO_2 emissions have been attributed to fossil-fuel burning and the remainder to land-use changes. The major impacts of agricultural land-use change are occurring in tropical rainforest regions such as Brazil, Congo, and Indonesia where native rainforests are being cleared for cultivation and pasture. Tropical deforestation, which now exceeds 13 Mha per year, is a substantial source of CO_2 . It also causes a moderate increase in albedo, which causes cooling of the air; however, this cooling is more than offset by warming of the air through reduction in evapotranspiration and through CO_2 emissions associated with deforestation.
- Fifteen years ago, the focus was on what to expect in the year 2100. Now there's more emphasis on the next 25 years, which is an indication of how much more seriously the problem is being taken. It is no longer an academic exercise.
- A 2007 report on how climate change will affect agriculture in the Canadian prairies stated, "The net impacts are not clear and depend heavily on assumptions including the effectiveness of adaptation." Per the title of this conference: adaptation may have tremendous effects in terms of crop yields, agricultural economics and food security.
- Extreme events in agriculture have received particular emphasis in the past 10 years. For example, the drought in the Canadian prairies in 2001–2002 caused losses in agricultural production equivalent to \$3.6 billion. Net farm income was negative for several provinces. However, adaptation measures could not completely offset the drought impact. This demonstrates that, even in advanced western society, increased adaptive capacity will be important.

GENETIC APPROACHES TO CROP ADAPTATION

- Since 2001/02, much of Australia's most productive agricultural land, primarily in the southeast, has experienced conditions of higher-than-average temperatures and lower-than-average rainfall; after several preceding years of drought, 2007 was one of the hottest growing seasons on record across much of Southern Australia,

with crop losses much larger than expected. This trend of declining rainfall and increasing temperatures is predicted to continue, emphasizing a need for scientific approaches to develop germplasm adapted to hostile conditions.

- Historically, improvement of tolerance to abiotic stresses has been a major target of plant-breeding programs globally. The major challenge, however, results from the complex nature of abiotic-stress-tolerance traits and the difficulty in dissecting them into manageable genetic components amenable to molecular breeding.
- Dissecting drought tolerance to the level of a single gene or group of genes amenable to genetic engineering will be difficult. A major challenge in the use of functional genomics to enhance the development of drought tolerance is to define the system and focus on key traits of interest.
- Various analyses suggest that increasing temperatures will pose a major constraint to crop production in the future. The warmest summers observed in the tropics and subtropics in the past century may be seen as normal by the end of the twenty-first century.
- Despite the trends of higher temperatures in many regions, protection against the devastating effects of low temperatures, particularly during the sensitive phases of seedling growth and crop maturation, remains an important focus area for crop improvement.
- Water-use efficiency is being recognized as a critically important trait in areas where crop production relies on dwindling supplies of sub-surface irrigation water or where there is competition for water between urban and agricultural demands.
- Some stress-protection mechanisms in plants appear to confer tolerance of multiple stresses, for example through effects on energy balance or detoxification of reactive oxygen species generated upon exposure to stress. Down-regulation of poly(ADP-ribose) polymerase (PARP) in *Arabidopsis* and canola increased tolerance of heat, drought and high light.
- In C₃ crops, photosynthesis is less than optimally efficient because of photorespiration, whereby a third of the fixed carbon is lost. The possibility of decreasing photorespiration is under research, thereby saving energy and improving the plant's resistance to stresses.
- Canola plants of a particular variety were grown under stress and non-stress conditions and separated into good performers (low respiration rate) and bad performers (high respiration rate) over several generations, producing a population with higher energy homeostasis under stress conditions. Analysis revealed that epigenetic variants had been selected, not mutants, with DNA methylation changes that correlate with good and bad performance. These changes occurred in coding regions of genes involved in stress response. When the superior epigenetic variants were crossed with hybrid lines, heterosis resulted in more leaf material and better growth under a range of stress conditions.

OTHER APPROACHES TO ADAPTATION

- Increased productivity of crop plants due to increased concentration of atmospheric CO₂ may force corresponding increases in fertilizer demand (especially for non-legumes), in order to achieve higher yield potentials. On the other hand, higher nitrogen-use efficiency under elevated CO₂ levels may mitigate increased demands for fertilizers. Application of plant-growth-promoting rhizobacteria (biofertilizers) and understanding signaling between bacteria and plants may also lead to improved crop productivity and, as a result, increase sequestration of carbon in roots; some of these signals also have the potential to increase legume nitrogen fixation, reducing nitrogen-fertilizer applications in the long term and, therefore, reducing N₂O emissions.
- Rising atmospheric temperatures will have both direct and indirect consequences for crop plants. Greater heat stress will likely be experienced more often by temperate-adapted species, potentially reducing their photosynthetic efficiency and increasing their susceptibility to pests, disease, and competition from weedy species. This will probably result in a need for more-frequent pesticide applications, more-careful pest monitoring, and development—including by genetic engineering—of pest- and disease-resistant crops.
- The northerly migration of pest and weed species in response to warmer conditions at higher latitudes poses serious challenges to growers unfamiliar with their management. Insect pests may increase their numbers of generations produced *per annum*, thereby increasing insect densities and associated predation of crops. Temperature rise and elevated CO₂ concentration could increase plant damage from pests in future decades. Weeds show a larger range of responses to elevated CO₂ than do crops, due to their greater genetic diversity. Increased wind speeds will facilitate the dispersal of disease spores.
- Elevated CO₂ can enhance photosynthesis and reduce transpiration, resulting in increased yields and more efficient use of water. The responses are more pronounced in species possessing the C₃ mechanism than in C₄ and CAM² species due to the CO₂-concentrating mechanisms of the latter two groups. Plants show numerous other responses to CO₂, including changes in phenology, leaf anatomy and dark respiration, but it is unclear whether these are direct responses to CO₂ or indirectly reflect effects of increased carbohydrate levels or of decreased transpiration.
- Crop-simulation models are widely used to predict impacts of climate change on agricultural production. In regions where climatic conditions permit year-round cropping, however, changes in planting dates and crop durations may allow important adaptive changes in cropping patterns. The ability of simulation models

²Crassulacean acid metabolism.

to predict how yield and phenology changes with planting dates make them highly suitable for examining temporal changes in crop sequences.

- The potential impacts of climate change on cropping patterns are highly researchable, but present significant methodological challenges. These impacts are not simply a question of increased or decreased productivity, but may have dramatic effects on land use as well as cropping practices. Ecological-niche modeling and crop-simulation modeling are powerful, complementary tools for examining the spatial and temporal aspects of climate-change impacts. Their successful application, however, requires effective interdisciplinary collaboration, including participation of plant biologists.
- Addressing the issue of climate change requires mitigation and adaptation. Mitigation implies either reducing emissions (by enhancing energy-production efficiency, and identifying low-C or no-C fuel sources) or sequestering emissions in long-lived pools (*e.g.* soil, biotic). Adaptation implies changing lifestyle and using technologies for management of resources in a manner that minimizes the adverse effects of climate change on soil and water resources.
- Crop yields increased by a factor of 3 to 5 during the second half of the twentieth century despite degradation of soil, desertification of land, and depletion/pollution of water resources. This quantum jump in yields and the overall increase in agronomic production was brought about by agricultural intensification through adoption of varieties that were responsive to fertilizer and irrigation inputs. However, future increases in irrigation, most likely to occur in Africa and South America, will exacerbate competition for water resources from rapidly increasing demands from non-agricultural (*e.g.* urban, industrial) uses.
- Demands for natural resources will increase drastically during the twenty-first century because of increased need for food/feed production, which may have to be doubled by 2050, and climate change which will further jeopardize the natural resources that are already under great stress. Adaptation to climate change will be essential for human well-being.
- When we think of the effects of climate change on future generations, needs for mitigation via lifestyle change and altered agricultural practice are clear. Predicted rises in sea level, destruction of traditional habitats and industries and loss of biodiversity push ethically acceptable climate policies strongly towards mitigation rather than adaptation.
- Important among several options for agricultural adaptation are choosing crop-management techniques including drought-tolerant (avoiding) and early-maturing varieties adopted in conjunction with adjustment in time of planting, and converting to farming/cropping systems that reduce risks and produce minimum assured returns in bad years rather than maximum production in good years, with focus on choice of appropriate species and diversification (mixed farming).

ETHICS, POLICY, CARBON CREDITS

- Ethics need to be distinguished from opinion. Surveys to determine what people think is right or wrong about climate change describe opinions rather than ethics. Too often, governments and industries make decisions based upon polls of people's opinions rather than on careful study of the ethical issues involved. Ethics is about *values* apart from people's opinions. Ethics assumes that some beliefs about right and wrong may be incorrect, and the study of ethics attempts to discover which are correct. In short, there is right and wrong above what people *think* is right and wrong, beyond people's opinions.
- Ethical decisions require that we combine scientific, social and economic facts relating to the threat of global climate change with general ethical principles that indicate right and wrong in all areas, and thus lead to specific policy recommendations.
- The Buddhist understanding of *karma* is that actions motivated by negative intentions tend to bring about adverse consequences, while actions motivated by good intentions tend to bring beneficial results. If our eagerness to develop and use transgenic animals is motivated by generosity, loving kindness and wisdom, which could include the mitigation of climate change, we can conclude that this technology is likely to bring good results. If, however, we are motivated by greed, ill will and delusion or ignorance, then we should expect this new technology to increase, rather than reduce, our suffering and frustration. This Buddhist approach does not imply that genetic engineering is bad in itself.
- In late 2009, the 15th Conference of the Parties under the Climate Convention will be convened in Copenhagen to address the directions laid out in the Bali Action Plan that countries agreed to in 2007 at the 13th Conference of the Parties. The Action Plan specified steps to be taken to "enable the full, effective and sustained implementation of the Convention through long-term cooperative action, now, up to and beyond 2012," which is after the end of the Kyoto Protocol commitment period. An agreed long-term global goal for emission reductions, to meet the Convention's objectives, is to be one outcome of the 15th Conference of the Parties, as well as interim targets. What those targets will be or even if there will be agreement on them, is uncertain. From an agriculture point of view, there will likely be important terminology, guidance and rules in the details. These details are even more difficult to predict.
- Designing adaptation policy for climate change will require, *inter alia*, assessments of the effectiveness, costs and feasibility of measures to reduce vulnerability; stakeholder analyses to identify targets and beneficiaries of adaptation interventions; and analyses of the consequences of inaction.
- As the climate changes, there will be stresses on agricultural production in some regions and opportunities in others. Will there be financial and regulatory sup-

port for diversification into other crops and for possibly relocating agriculture production to other areas? If so, in the latter case, will there be investments in public infrastructure, such as transportation and water supply, to support the new region?

- Production of the three main greenhouse gases—carbon dioxide, methane and nitrous oxide—can be mitigated through agricultural activities. Management practices can be altered or changed in many ways to reduce emissions, to enhance the removal of carbon dioxide from the atmosphere (C sequestration), or to displace emissions from fossil fuels by using crops or residues as sources of energy. Displacing fossil-fuel emissions with bioenergy from crops represents an important opportunity for agriculture and remains a fertile topic for research as governments continue to rely on renewable fuel standards as an important component of energy and climate-change policies.
- When evaluating a mitigation option, an important aspect is the distinction between the technical potential and the economic potential that an agricultural practice represents. Technical potential refers to the biophysical ability of a management practice to reduce emissions, but does not take into account its cost-effectiveness.
- The fact that science has demonstrated the potential for agriculture to provide emissions offsets under a cap-and-trade program and that including offsets as part of policy design may significantly decrease the cost of such programs is not enough to ensure the environmental integrity of legislation or international agreements that aim to mitigate the effects of climate change. The most substantive issues that must be addressed in order for agricultural offsets to be an effective component of a regulatory (non-voluntary) cap-and-trade program are verifiability, enforceability, additionality, and permanence.